

Critical analysis of localization of micro-hydropower plant in the superior basin of Argeş river

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Abstract. The purpose of this work is to anticipate the most important consequences generated by the installation of a micro-hydropower plant on mountain rivers, on the main components of the environment, and also to identify and locate the potential disruptions caused by the implementation of these projects. In addition, the authors would like to clarify certain aspects regarding the changes brought to the natural setting, the extent to which they affect the components of the environment, the capacity of nature to withstand these micro-hydropower plants and to naturally or artificially recover after the project is put into operation. Another aim is to establish measures for limiting the modifications that appear in time due to the installation of the micro-hydropower plants in order to ensure the good functioning of the respective plants. The main anthropic factors, that represent the subject of the analysis, act synergically, thus making it difficult to understand the impact of this project on the environment, especially since nature recovers itself under certain circumstances.

1 Introduction

The micro-hydropower plants (MHC) in the superior basin of the Argeş River are located on the Capra and Buda Streams. These two tributaries of Argeş river spring from the main peak of the Făgăraş Mountains and lose their waters in Vidraru reservoir (Figure 1).

The average installed power of each micro-hydropower plant is about 2 MW, and the average output is about 1.12 MW / h. As a result, the combined power of the micro-hydropower plants on the Capra and Buda Streams is about 14.7 MW / h. The entire amount of energy produced is delivered to the national energy network.

The two tributaries of the Argeş River, respectively the Buda and Capra streams from the southern slope of the Făgăraş Mountains, where the 12 micro-hydropower plants are located, are included in NATURA 2000 site (Figure 2).

That is why their construction was interrupted by launching the infringement procedure against Romania, in 2015. The European Commission and the authorities had the negative aspects: the construction of an extra water inlet on the Buda stream, although the investors were not entitled, the burial of the pipes, which was not part of the technical solution agreed

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by the authorities, the project being modified along the way, and the notices came later that there was no legal right to cross the public domain of the state without a lease agreement.

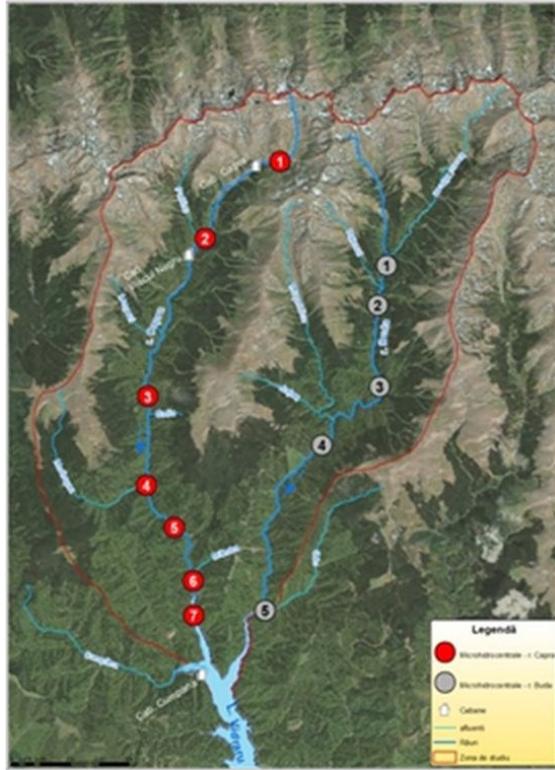


Fig. 1. Localization of micro-hydropower plants on the Capra and Buda Streams

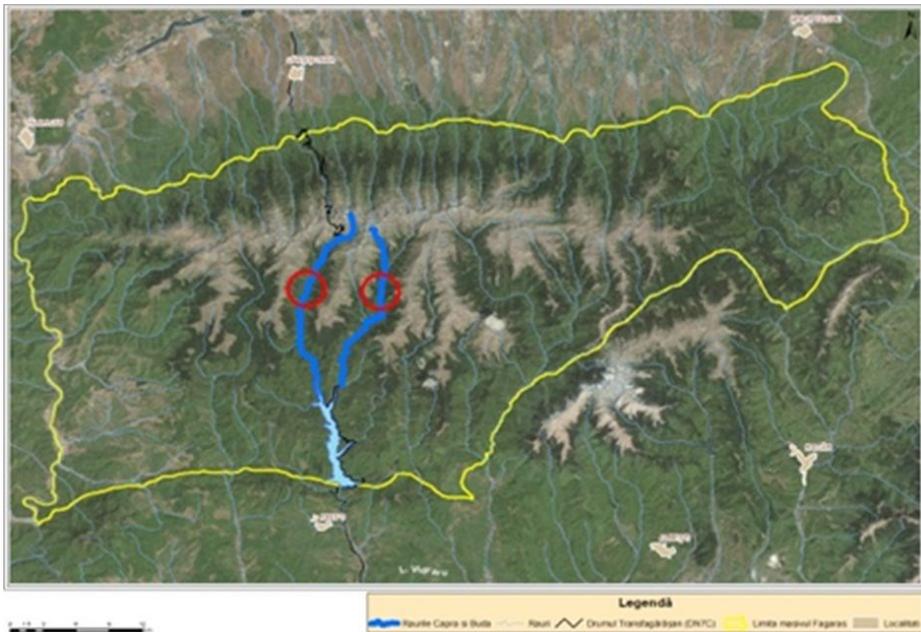


Fig. 2. The studied area in the Făgăraș Mountains community site

Also, fish scales do not match from the point of view of recommended parameters, being under-dimensioned to what the project requires. Moreover, being a stream embedded in NATURA 2000 site, excavator tracks and bulldozers were not allowed to enter the river bed. The burial of the micro-hydropower plants pipelines was supported by flood protection measures (the only legal framework that allowed the machines to bother the streams).

Because of these irregularities, we considered that identifying the impact of MHC on environmental components is a necessary step.

2 Impact on surface and underground waters

From the spring to the flow, a significant part of the Capra stream's water is captured and used to produce energy. By building micro-hydropower plants, the captured water comes through a pipeline from one MHC to the next.

Each micro-hydropower plant has, in addition to the pipes through which the upstream water comes, a water catchment dam that comes from the side streams. Building such a water intake is a difficult intervention on the territory and on ecosystems because it irreversible affects the environment, not only in the vicinity of the dam but also downstream: there occurs modifications on the water velocity, its oxygenation, the thermal balance as well as and the concentration of nutrients, while clogging the bed.

By introducing machines into the bed (Figure 3), the natural course of the river/stream interferes with water becoming a mixture of mud and rock particles in which every form of life disappears.

We took samples from different locations on the Capra Stream and analyzed them. From the analysis of Zn concentrations in water samples, values slightly above the normal range were found. The observed exceedences were of 0.08 mg/l. We collected Pb and Cd samples, but their concentrations were practically null. Knowledge of heavy metal concentrations in mountain aquatic ecosystems is necessary because of their toxic effects on living organisms. Even in lower concentrations, in the form of salts, these metals can cause extremely severe degradation of the aquatic environment.



Fig. 3. Machinery in the bed of Capra stream

Suspensions are present in the stream water as organic and mineral materials. During MHC's construction and placing works the amount of suspensions reached very high values, the maximum values were up to 58.8 mg/l, while normal value of turbidity on the Capra River was 27.7 mg/l (1).

Solid suspensions caused an increase in water turbidity. In addition to clogging the stream bed, increasing the amount of suspensions in water can cause asphyxiation of fish [1].

The maximum temperature of Capra's Stream is recorded from July to August and is about 9°C, and the minimum value of the temperature is recorded from December to March and is around -3° to 0°C (10). During the project implementation period, we measured the water temperature in March, downstream of the site of Capra VI micro-hydropower plant. We noticed that the water temperature was about 2°C, higher than the average value for that date.

We took a sample of water during the construction of the Capra VI MHC and, following the laboratory analysis, we found slight changes of other physico-chemical and microbiological parameters. The ionic reaction of the water depends on the presence of dissolved acids. The water of the Capra stream has a neutral or slightly alkaline reaction, the average pH value being 7.8-7.9 during the arrangement works. After the MHC's commissioning the pH value recorded a slight increase of up to 8, the waters being more alkaline (11).

The natural amount of dissolved oxygen at the maximum potential value of 11.31 mg/l decreased because the natural stream's bed pathway was straightened, irreversible change, thus eliminating the possibility of water oxygenation by natural fall, but also due to the slight increase of the water temperature. The pronounced decrease of the flow determines an increase of the water temperature and implicitly a decrease of the dissolved oxygen content, essential element for the life in the mountain waters (Figure 4). The optimal amount of dissolved oxygen should be maintained above 9 mg/l (2).

Decrease of flow determines restricting the wetted surface of the bed and reduces the amount of benthic fauna. In the case of rivers in mountainous areas with narrow bad in rocky valleys such as the Capra Stream, endogenous fauna is affected when water velocity drops significantly below 0.5 m/s, the representative fauna becoming the low current (12), developed in the mud, to the detriment of the lotic fauna which inhabits rapidly moving fresh water with a velocity of 0.5 to 1 m/s, developed in algae (*Cladophora*) and in the muscles of rocks (*Fontinalis*).

The damage in this case is qualitative, benthic fauna specific to mountain rivers being consumed predominantly by fish, with a high nutritional intake.

The groundwater level changes due to deforestation, resulting in a negative impact on the biotope. Underground waters have also been affected by the modification of the river's natural bed. If before the project, we measured the width of the bed of 10.5-12 m, after completion of the construction, it was reduced to 2-4.5 m, which led to the lowering of the groundwater level and implicitly to changing riparian habitats of water-loving plants such as burdock (*Arctium lappa*) and *Tozzia carpathica* herbaceous plant on which the birds and insects with which they feed themselves depend.

With the appearance of a larger water mirror instead of the running water, but also by modifying the geomorphological structure of the bed, the cascades disappearing and the bedding being thus straightened, water quality has deteriorated by reducing nutrients and oxygen, changes in the hydrostatic level of groundwater but also a reduction in the flow of river, which results in a substantial modification of the ichthyofauna and the ichthyoflora, both as distribution and as a diversity.

3 Impact on soil

The main forms of degradation of the soil from the vicinity of a micro-hydropower plant under construction consist of ground clearance and complete disappearance of the vegetal soil.

Degradation of the stream bed can cause soil erosion processes in the vicinity of watercourses and even effective soil losses (Figure 4).

Projects involving rock excavations can lead to disturbance to the water balance, generating erosion processes and lowering the bed's share both downstream and upstream of the area where the micro-hydropower plant is to be located.



Fig. 4. Soil degradation

By carrying out works along the water courses, the soil was compacted along the bed, the project also involving the traffic of heavy machinery.

Also, the slopes in the immediate vicinity of micro-hydropower plants become unstable after vegetation cuts, on narrow surfaces.

This has caused the erosion of the soil and has created the premises of local landslides, which in turn lead to the destruction of the vegetal soil.

4 Impact on air

A profound intervention, altering the atmospheric balance, is the change on microclimate as a result of the appearance of large water mirrors, or the accumulation lakes serving micro-hydropower plants.

The main meteorological parameters: rainfall, temperature, wind and atmospheric humidity are altered over a relevant period of time, so that over time there are changes in the natural biological regime, which consist in the reduction/drying up to the disappearance of some vegetation or fauna elements.

The transition from the mountain streams to a series of five small reservoirs on the Buda Stream (Figure 5) and seven on the Capra Stream led to the increase of local humidity and the production of fog under certain conditions.



Fig. 5. Accumulation dam on the Buda Stream

5 Impact on ecosystems

The area approved by RNP Romsilva to be removed from the forest fund is approximately 0.2384 ha for each micro-hydropower plant [2].



Fig. 6. Modification of hydrological balance, degradation of vegetation, Buda Valley

The location of the building, the water intake and a large part of the water supply pipeline led to quantitative deforestation of the vegetation along the stream bed, where we reported the existence of forests with a protective function of the slopes: spruce forests (*Picea abies*), beech (*Fagus sylvatica*), fir (*Abies alba*), *Hieracium rotundatum* and white antin (*Alnus incana*). The shores have been substantially widened at the construction site of the micro-hydropower plant, which has been achieved by the complete decay of the soil, causing the degradation of the forest vegetation and existing grass and the loss of rare specimens trees and flowers: *dentaria glandulosa*, observed in wet places with snow melt waters on the banks of the Capra stream and the *Tozzia carpathica* mountain plant [3].

The riparian vegetation has also been altered by the change in water balance (Figure 6), respectively the variation of the hydrostatic level along the Capra Valley.



Fig. 7. Micro-hydropower plants pipes

The Capra and the Buda Valley are important areas of fauna, with a vast area of hunting for different species of wild animals: bears (*Ursus arctos*), wild boar, lupins (*Canis-lupus*),

lynx (*Lynx lynx*) and foxes, with numerous shelters, wildlife and wintering grounds, as well as breeding and transit corridors.

The faunistic species present in the area, which found here the three basic conditions for existence, namely food, quietness and shelter, were influenced by the construction of micro-hydropower plants by the increase of the noise level due to the traffic of heavy vehicles, by the presence of people and the equipment that removed sensitive fauna species.

The foresters in the area have indicated that the negative impact is seen on large conserved carnivores, including the bear (*Ursus arctos*), which have significantly changed their migration routes, thus changing their seasonal movement to the breeding and feeding areas.

Linear infrastructures, hydrological derivations and accumulations on watercourses influence the flow regime, reducing availability for aquatic life.

The water intakes and the spill threshold of each micro-hydropower plant require interruptions of ecological continuity in flowing water ecosystems. Achieving a too steep fish ladder involves discontinuing upstream aquatic fauna, as is the case with indigenous trout, species that have to swim upstream the Capra and Buda Streams in certain phases of its vital cycle but also other animals such as the water chute and the otter.

The steel duct that accompanies one of the banks of the stream bed, from the first micro-hydropower plant to the water inlet of the last micro-hydropower plant, does not provide optimal conditions for the fish population, trout living in very oxygenated water. There is no light in the pipe (Figure 7), the fish do not have food, and the humidity is very high.

All of this has irremediably affected the biodiversity of the studied area, leading to alarming fishing mortality in the Buda Stream and the actual lack of fish in the Capra Stream, as there is a nearly dry, non-flowing bed in place of a mountain stream with constant an ecological flow (Figure 7), as required by the law and no longer provides living conditions for fish.

On the Capra stream, studies have been carried out in order to assess the impact of an hydrological arrangement on the environment, in 2012 [4].

In this regard, several sampling stations were located, the results of which reflected the disappearance of indigenous trout to certain sectors.

Two fishing methods were used to determine the fish populations: fishing with electrofishing and fixed bag fishing (Figure 8).



Fig. 8. Fishing with electrofishing and fixed bag fishing methods

These two modern methods of fishing, applied in the waters of the Capra stream, revealed the total lack of lute (*Cottus gobio*) at all times of analysis. They also highlighted the lack of indigenous trout in all the seasonal harvesting campaigns of the mountain water.

This is mainly due to the negative anthropic impact of the last decades and especially due to the impossibility of natural repopulation due to the presence of accumulation dams, which interrupts the natural longitudinal connectivity, which normally ensures the migration of the ichthyofauna.

In conclusion, due to the historical impact, the ichthyofauna was significantly affected, so that on the Capra stream course of the *Cottus gobio* species practically disappeared. Indigenous trout specimens inhabit a narrow stretch of only 2-3 km between the altitude of 1100 m and 1300 m.

The lack of these fish fauna elements in the sector under discussion is also due to the work done for several years in a row since the communist period for the realization of the Vidraru reservoir, the Transfăgărășan highway, but also the rudimentary transport mode of the logs, respectively on the water, especially where the high flow of the river allowed this.

It should also be noted that the natural repopulation of the Capra stream (upstream of Vidraru Lake) is impossible due to the longitudinal connectivity interrupted by hydrotechnical works.

Based on the field observations and measurements as well as the results obtained by the engineer dr. Ioan Cristea in the study carried out on all mountain fishing funds in our country, we have developed an impact matrix (Table 1), highlighting the impact of the location of the micro-hydropower plants on the upper basin of Argeș river on environmental components [5].

Analyzing the matrix below, we noticed that the main activities generating a consistent impact are the excavation of the banks and the water bed under study, as well as the accumulation of water as a result of building of storage barrage, -15/+2, respectively -13/+4.

The positive impact generated by a micro-hydropower plant in the operating phase has high values on the forest and tree vegetation cover of +8, but also on the edificant cover, +6, values explained by the reforestation and the reclamation of vegetal soil that are done with the completion of hydrotechnical works. Higher positive values of +4 were also obtained in the case of maintenance works of these projects executed by investors, supported by created jobs for the population in that area.

As environmental components, the valleys and river banks, surface waters, ichthyofauna originally abundantly and implicitly the ecosystems, as well as tourist activities in the area, suffered the most.

There are also reversible changes in the environmental components, so the vegetation cover is regenerated either naturally or artificially, by replanting, and the vegetal soil recovers where necessary, air pollution disappears by increasing moisture in area.

5 Solutions

Starting from the idea that man must protect nature that has not been affected by anthropic activity and restore what has been destroyed so as to achieve a lasting balance of ecosystems in time, there will be presented some solutions to diminish the negative impact that has the micro-hydropower plants on the environment, thus creating a natural environment-human harmony.

The significant anthropogenic impact of micro-hydropower plants on mountain aquatic ecosystems in the analyzed area has caused the salmonid area to be restricted [5].

After the construction of micro-hydropower plants, ecological rehabilitation of the fishing fund is required, namely the repopulation of this stream sector with *Cottus gobio* (Figure 9, left) and common trout (Figure 9, right), species that before the anthropic impact had stable populations here. Repopulations are recommended to be made with biological material from nearby rivers that have similar characteristics and have suffered less from anthropogenic impact.

Tab. 1. Impact matrix for an operating micro-hydropower plant

Operating MHC Environmental components	Works in the riverbed (bank and riverbed excavation)	Water accumulation in	Operation of MHC	Emissions of dust particles, gas from	Production of renewable energy	Maintenance of MHCs	Removing the vegetal soil	Deforestation	Building access ways	Cumulative Impact on Environmental Factors
Air quality			-1					+1		-1/+1
Microclimate	-1	-3						+1		-4/+1
The presence of vegetal soil	+1	-1					+2	+1	-1	-2/+4
Soil compaction						-1			-1	-2
Surface waters	-2	-2/+1	-2		+2	-1				-7/+3
Oxygen dissolved in water	-2	-1				-1				-4
Underground waters	-1	-1	-1				+1			-3/+1
Turbidity						-1				-1
Changing vegetation	+1	+1					+1	+2	+1	+6
Changing fauna	-3	-2	-1		-2		+1	+1	+1	-8/+3
Ecosystems		-1	-1			-1	+1	+2	+1	-3/+4
Morphology of the stream's bed	-2	-1				+2				-3/+2
Slope processes						+1		-1		-1/+1
Landscape quality	-1	+1					-1	-1	-1	-4/+1
Socio-economic activities	-2	+1	+1		+1	+1				-2/+4
Risks	-1	-1	-1		-1			-2		-6
The cumulative impact of activities on the environment	-15/+2	-13/+4	-7/+1	0	-3/+3	-5/+4	-1/+6	-4/+8	-3/+3	-51/+3



Fig. 9. Cottus gobio (left); Common trout (right)

In the river segments where the ichthyofauna was less affected, in the upper course of the Capra Valley and certain sections of the Buda Stream, a 4-years restriction on recreational-sport fishing could be imposed for the restoration of existing populations up to the normal level and limits.

For the recovery of these funds over a 4-year period of reproduction cycle for common trout, these streams must also be protected by harvesting 25% of salmon productivity, the theoretical harvest calculated.

In addition to the minimum required flow on downstream of the dam, an essential change is made on the stairs, which establish the connection between the accumulation basin upstream of the water inlet and the downstream course. Their installation and functionality are extremely important, as salmon populations have deteriorated quantitatively and qualitatively downstream of dams.

Although all 12 dams are provided with fish stacks, they are not functional as they are set on the banks and often the volume of water is insufficient.

An efficient solution, for upstream access of common trout (*Salmo trutta fario*) to spawning, would be the correct dimensioning of fish steps and the positioning of the ladder foot downstream of the main stream, because the trout instinctively chooses the most difficult route but provides maximum protection and survival of the species.

For the upstream access of the common trout (*Salmo trutta fario*) to spawning, the foot of the ladder should be placed downstream in the main stream because the trout instinctively chooses the most difficult route which provides maximum protection and survival of the species. In order to perpetuate the scale of the fish staircase, it must be arranged with a plume brought from the Capra or Buda Stream, to simulate the natural "site" that will maintain a water level of about 20-30 cm, for the rest and shelter of the fish in transit. The step should not be more than 30 cm high and 100-200 cm wide for the ergonomic migration of salmonids. The upstream end of the fish ladder must be positioned in an adjustable spillway from the reservoir dam.

A significant negative impact also occurs on the forest and trees on the banks of the streams. The forests in the area are state property, which justifies a reservation regime in which the only cuts allowed will be gardening or sanitation, for total protection of the river basin's soil and banks. Considering the very high conservative value of the habitat, the authors propose as a measure to reduce the impact the reconstruction of same type of habitat after the location of the ducts, along the entire length of the adduction.

As a result of investments made, upstream of the Vidraru reservoir, the area no longer meets the trophic and ambient requirements of terrestrial fauna. In this regard, there can be mentioned otters, whose trophic base has been practically eliminated.

An efficient solution after the completion of the works is the ecological reconstruction of the slopes, banks and bed, which has been visibly narrowed (Figure 3), thus enabling the species to return to the affected area.

Another alternative to avoid deforestation would be to identify on these sectors solutions to avoid habitat loss by modifying the path of the pipeline.

For the habitat improvement, as a shelter for fish, in the minor stream bed can be placed large river stones from the meadow / major bed, singular or pyramidal type groups, preferably located in the main stream, or attached to the grassed banks on the linear sections. This will also make artificial meanders, improving the slope coefficient of the banks, implicitly achieving their protection against erosion. This proposed alternative is an ecological alternative that excludes wood cutting, involves minimal labor costs and rebuilds the natural "sit".

In addition to these measures, the authors recommend complying with current legislation as well as improving it, as well as tracking and implementing the proposed project, backed by the approvals and authorizations obtained by investors in the initial phase, while severely penalizing contraventions if this is found.

5 Conclusions

In conclusion, at the end of our analysis, we found that the main dangers threatening mountain rivers are not poaching, excessive anthroping or physico-chemical pollution of water, but the hydropower policy that is currently at the forefront of environmental reasons of protecting biodiversity.

In conclusion of this analysis, we have noticed that the main threats to mountain rivers are not poaching, anthropic activity or physical-chemical pollution of water, but the hydropower policy that is currently at the forefront of environmental protection of biodiversity, flora and fauna.

Another important aspect is that there is also a lack of ecological education of the population, in this sense it is necessary to highlight in a series of educational measures the necessity to protect the nature, as well as the lack of legislation conforming to the natural environment and sustainable hydro-energetic valorisation.

Through this approach we wanted to clarify some aspects regarding the magnitude of the changes made to the natural landscape by the construction and operation of micro-hydropower plants. We have shown how they affect the environmental components, the ability of the natural environment to cope with the construction of micro-hydropower plants and to re-establish the measures to limit and improve the changes generated by the installation of micro-hydropower plants, so that they can function where the characteristics of hydrological bodies allow this under the conditions of a real agreement with the environment.

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